SULFUR

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The United States was once again the world's leading sulfur producer in 2003 with 9.6 million metric tons (Mt). The sulfur was produced as a byproduct of efforts to meet environmental requirements that limit atmospheric emissions of sulfur dioxide. Worldwide, regulations forced increased sulfur recovery for environmental reasons, resulting in a continued decline in the production of native sulfur and pyrites. Production outpaced sulfur demand, which resulted in increased stocks at some operations, especially at a few in remote locations from which it is difficult and costly to ship the product to market.

Through its major derivative, sulfuric acid, sulfur ranks as one of the most important elements used as an industrial raw material and is of prime importance to every sector of the world's fertilizer and manufacturing industries. Sulfuric acid production is the major end use for sulfur, and consumption of sulfuric acid has been regarded as one of the best indices of a nation's industrial development. More sulfuric acid is produced in the United States every year than any other chemical; 41.0 Mt, which is equivalent to about 13.3 Mt of elemental sulfur, was produced in 2003; this was 4.6% more than that of 2002 (U.S. Census Bureau, 2004).

In 2003, domestic production and shipments of sulfur in all forms were 3.5% and 3.7% higher, respectively, than those of 2002. Consumption increased, as did imports and prices (table 1; figures 1-4). The United States maintained its position as the leading world consumer of sulfur and sulfuric acid. The quantity of sulfur recovered domestically during the refining of petroleum continued the upward trend established in 1939, the second year that such production was reported, by increasing by 3.3%. Sulfur recovered from natural gas processing increased by 11.0%.

Byproduct sulfuric acid from the Nation's nonferrous smelters and roasters, produced as a result of laws restricting sulfur dioxide emissions, supplied a significant quantity of sulfuric acid to the domestic merchant (commercial) acid market. Production from this sector decreased by 11.5% as a result of decreased recovery at copper smelters. Three copper smelters, one lead smelter, one molybdenum smelter, and one zinc smelter reported production of byproduct sulfuric acid.

Estimated world sulfur production was slightly higher in 2003 than it was in 2002 (table 1). Recovered elemental sulfur is produced primarily during the processing of natural gas and crude petroleum. For the third consecutive year, about 90% of the world's elemental sulfur production came from recovered sources. Some sources of byproduct sulfur are unspecified, which means that the material could be elemental or byproduct sulfuric acid. The quantity of sulfur produced from recovered sources was dependent on the world demand for fuels, nonferrous metals, and petroleum products, not for sulfur.

World sulfur consumption was slightly higher than it was in 2002; about 50% was used in fertilizer production, and the remainder, in myriad other industrial uses. World trade of elemental sulfur increased by 10% from the levels recorded in 2002. Worldwide inventories of elemental sulfur were slightly higher.

Legislation and Government Programs

Late in 2003, the U.S. Environmental Protection Agency (EPA) issued a report finding that U.S. refiners were on target for meeting the 2006 deadline for low-sulfur diesel fuel. By that time, an estimated 96% of diesel fuel produced in the United States will meet the 15-part-per-million (ppm) standard (Oil & Gas Journal, 2003b).

Earlier in the year, the EPA proposed standards intended to reduce pollution from diesel-powered off-road vehicles to match the requirements for on-road vehicles. Included in the rules are changes to the design for new engines for off-road vehicles that would limit emissions, including those of nitrogen oxides, particulates, and sulfur dioxide. In addition to changes in diesel engine design, fuel specifications will also change. The sulfur limit in fuels for off-road vehicles will be reduced in two steps. The sulfur limit will be reduced to 500 ppm from 3,400 ppm by 2007, and further reductions will take it to 15 ppm in 2010 (Fialka, 2003).

Production

Elemental Sulfur.—U.S. production statistics were collected on a monthly basis and published in the U.S. Geological Survey (USGS) monthly sulfur Mineral Industry Surveys. All of the 108 operations to which survey requests were sent responded; this represented 100% of the total production listed in table 1. In 2003, production and shipments were about 5% higher than those of 2002. The value of shipments was 2.5 times higher than in 2002 owing to a similar increase in the average unit value of elemental sulfur. Trends in sulfur production are shown in figures 1 and 3.

Frasch.—Until 2000, native sulfur associated with the caprock of salt domes and in sedimentary deposits in the United States was mined by the Frasch hot-water method in which the native sulfur was melted underground with super-heated water and brought to the surface by compressed air. Freeport-McMoRan Sulphur Inc. (a subsidiary of McMoRan Exploration Co.) closed the last domestic Frasch mine, Main Pass, in 2000 (Fertilizer Markets, 2000).

Recovered.—Recovered elemental sulfur, which is a nondiscretionary byproduct from petroleum-refining, natural-gas-processing, and coking plants, was produced primarily to comply with environmental regulations that were applicable directly to emissions from the processing facility or indirectly by restricting the sulfur content of the fuels sold or used by the facility. Recovered sulfur was produced by 38 companies at 108 plants in 26 States and 1 plant in the U.S. Virgin Islands. Most of these plants were small with only 33 reporting production that exceeded 100,000 metric tons per year (t/yr). By source, 78.2% of recovered elemental sulfur production came from petroleum refineries or satellite plants that treated refinery gases and coking plants, and the remainder was produced at natural-gas treatment plants (table 3).

The leading producers of recovered sulfur, all with more than 500,000 metric tons (t) of sulfur production, in descending order of production, were Exxon Mobil Corp., BP p.l.c., ChevronTexaco Corp., ConocoPhillips Co., Shell Oil Co. (including its joint-venture and subsidiary operations), and CITGO Petroleum Corp. (including its joint-venture refinery). The 53 plants owned by these companies accounted for 68.4% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

Four of the world's 16 largest refineries, each with capacity of at least 400,000 barrels per day (bbl/d), are in the United States. They are, in decreasing order of production, ExxonMobil's Baytown, TX, refinery; Hovensa LLC's St. Croix, VI, refinery; ExxonMobil's Baton Rouge, LA, refinery; and BP's Texas City, TX, refinery (Nakamura, 2003). Refining capacity does not necessarily mean that these refineries were the leading producers of refinery sulfur. Sulfur production depends on installed sulfur recovery capacity as well as the types of crude oil that are refined at the specific refineries. Major refineries that process low-sulfur crudes may have relatively low sulfur production.

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 7.1% of the total domestic production of sulfur in all forms; this was a decrease of 11.5% compared with that of 2002 (table 4). Three acid plants operated in conjunction with copper smelters, and three were accessories to lead, molybdenum, and zinc smelting and roasting operations. The three leading sulfuric acid plants were associated with copper mines and accounted for 86.4% of the output. The copper producers—ASARCO Incorporated, Kennecott Utah Copper Corp., and Phelps Dodge Corp.—each operated a sulfuric acid plant at their primary copper smelters.

Consumption

Apparent domestic consumption of sulfur in all forms was 4.6% higher than that of 2002 (table 5). Of the sulfur consumed, 73.5% was obtained from domestic sources—elemental sulfur (68.4%) and byproduct acid (5.1%)—compared with 74.6% in 2002 and 79.9% in 2001. The remaining 26.5% was supplied by imports of recovered elemental sulfur (24.0%) and sulfuric acid (2.5%). The USGS collected end-use data on sulfur and sulfuric acid according to the standard industrial classification of industrial activities (table 6).

Sulfur differs from most other major mineral commodities in that its primary use is as a chemical reagent rather than as a component of a finished product. This use generally requires that it be converted to an intermediate chemical product prior to its initial use by industry. The leading sulfur end use, sulfuric acid, represented 62.7% of reported consumption with an identified end use. Some identified sulfur end uses were tabulated in the "Unidentified" category because these data were proprietary. Data collected from companies that did not identify shipment by end use also were tabulated as "Unidentified." A significant portion of the sulfur in the "Unidentified" category may have been shipped to sulfuric acid producers or exported, although data to support such an assumption were not available.

Because of its desirable properties, sulfuric acid retained its position as the most universally used mineral acid and the most produced and consumed inorganic chemical, by volume. Data based on USGS surveys of sulfur and sulfuric acid producers showed that reported U.S. consumption of sulfur in sulfuric acid (100% basis) increased by 6%. Data from that survey, however, showed total sulfur consumption was more than 20% higher than that of 2002, a figure that is much higher than reasonable expectations would warrant. Reported consumption figures do not correlate with calculated apparent consumption owing to reporting errors and possible double counting in some data categories. Significant increases in industrial end use data in 2003 are a result of more complete reporting from companies than in 2002. These data are considered independently from apparent consumption as an indication of market shares rather than actual consumption totals.

Agriculture was the leading sulfur-consuming industry; consumption increased slightly to 8.51 Mt compared with 8.46 Mt in 2002. Reported consumption of sulfur in the production of phosphatic fertilizers was about the same as that of 2002. According to export data from the U.S. Census Bureau (2004), the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers increased by 9.3% to 5.2 Mt.

The second leading end use for sulfur was in petroleum refining and other petroleum and coal products. Producers of sulfur and sulfuric acid reported a 55% increase in the consumption of sulfur in that end use. Changes in the refining industry indicate increases in refinery processes that require sulfur and sulfuric acid, but the dramatic increases are probably also owing to improved survey response in addition to increased consumption. Demand for sulfuric acid in copper ore leaching, which was the third leading end use, decreased by 40% as a result of continued low copper production from leaching operations and limited sulfuric acid availability in the regions of the United States where these operations are located.

The U.S. Census Bureau (2004) also reported that 2.85 Mt of sulfuric acid was produced as a result of recycling spent and contaminated acid from petroleum alkylation and other processes. Two types of companies recycle this material—companies that produce acid for consumption in their own operations and also recycle their own spent acid and companies that provide acid regeneration services to sulfuric acid users. The petroleum refining industry was believed to be the leading source and consumer of recycled acid for use in its alkylation process.

Stocks

Yearend inventories held by recovered elemental sulfur producers decreased to 206,000 t, or about 14% more than that of 2002 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to about a 6-day supply in 2003, compared with a 6-day supply in 2002, an 8-day supply in 2001, a 6-day supply in 2000, and a 12-day supply in 1999. Final stocks in 2003 represented 3.6% of the quantity held in inventories at the end of 1976 when sulfur stocks peaked at 5.65 Mt; this was a 7.4-month supply at that time (Shelton, 1978, p. 1296).

Although markets were favorable throughout the year, U.S. producers on the Gulf of Mexico were planning for the possibility of excess supplies in the future. Most refineries face difficult choices when sulfur production exceeds demand and could be forced to curtail refining without an outlet for the sulfur produced. For this reason, ExxonMobil, the leading sulfur producer in the United States, was considering the construction of a sulfur-forming plant somewhere on the Gulf Coast, providing the possibility of exporting formed sulfur, if the need should arise. The company was seeking support from other producers and contemplating the best site for the plant (North American Sulphur Review, 2003b).

Prices

The contract prices for elemental sulfur at terminals in Tampa, FL, which are reported weekly in Green Markets, began the year at \$56.50 to \$59.50 per metric ton. In April, prices increased to \$68.50 to \$71.50 per ton and remained there until July when they fell to \$64.50 to \$67.50 per ton. Contract prices rose in October to \$67.50 to \$70.50 per ton and remained at that level through the remainder of the year.

Based on total shipments and value reported to the USGS, the average value of shipments for all elemental sulfur was estimated to be \$28.71 per ton, which was 142% higher than that of 2002. This dramatic increase was a result of increased demand worldwide. Prices continued to vary greatly on a regional basis, which caused the price discrepancies between Green Markets and USGS data. Tampa prices were usually the highest reported because of the large sulfur demand in the central Florida area. At the beginning of 2003, U.S. west coast prices were listed at \$0 per ton, although, in reality, west coast producers can often face negative values as a result of costs incurred at forming plants. These costs were necessary to make solid sulfur in acceptable forms, often known as prills, to be shipped overseas. The majority of west coast sulfur was sent to prillers who may have been subsidized by the refineries, and the formed sulfur was shipped overseas. By March, however, increased international demand spurred the increase of west coast prices to between \$15 and \$20 per ton.

Foreign Trade

Exports of elemental sulfur from the United States, which included the U.S. Virgin Islands, as listed in table 7, were 8.0% higher in quantity than those of 2002 and 15.1% higher in value because the average unit value of U.S. export material increased to \$62.08 per ton. Exports from the west coast were 651,000 t, or 87.7% of total U.S. exports.

The United States continued to be a net importer of sulfur. Imports of elemental sulfur exceeded exports by more than 2 Mt. Recovered elemental sulfur from Canada and Mexico delivered to U.S. terminals and consumers in the liquid phase furnished about 91.2% of all U.S. sulfur import requirements. Total elemental sulfur imports increased by about 12.0% in quantity and higher prices resulted in the value being more than 2.5 times what it was in 2002. Imports from Canada, mostly by rail, were 6.7% higher in quantity, and waterborne shipments from Mexico were 24.2% higher than those of 2002 (table 9). Imports from Venezuela were estimated to account for about 8.8% of all imported elemental sulfur.

In addition to elemental sulfur, the United States also had significant trade in sulfuric acid. Sulfuric acid exports were 39.2% higher than those of 2002 (table 8). Acid imports were 4.42 times greater than exports (tables 8, 10). Canada and Mexico were the sources of about 61% of U.S. acid imports, most of which were probably byproduct acid from smelters. Canadian and some Mexican shipments to the United States came by rail, and the remainder of imports came primarily by ship from Europe. The tonnage of sulfuric acid imports was 14.2% lower than that of 2002, and the value of imported sulfuric acid decreased by 15.4%.

World Industry Structure

The global sulfur industry remained divided into two sectors—discretionary and nondiscretionary. In the discretionary sector, the mining of sulfur or pyrites is the sole objective; this voluntary production of native sulfur or pyrites is based on the orderly mining of discrete deposits with the objective of obtaining as nearly a complete recovery of the resource as economic conditions permit. In the nondiscretionary sector, sulfur or sulfuric acid is recovered as an involuntary byproduct; the quantity of output subject to demand for the primary product irrespective of sulfur demand. Nondiscretionary sources, once the primary sources of sulfur in all forms, represented 9.6% of the sulfur produced in all forms worldwide as listed in table 11.

Poland was the only country that produced more than 500,000 t of native sulfur by using either the Frasch or conventional mining methods (table 11). Small quantities of native sulfur were produced in Asia, Europe, and South America. The importance of pyrites to the world sulfur supply has significantly decreased; China was the only country of the top producers with more than 500,000 t of sulfur produced whose primary sulfur source was from pyrites. About 74% of world pyrites production was in China.

Of the 22 countries listed in table 11 that produced more than 500,000 t of sulfur, 14 obtained the majority of their production as recovered elemental sulfur. These 22 countries produced 91.5% of the total sulfur produced worldwide. The international sulfur trade was dominated, in descending order of quantity, by Canada, Russia, Saudi Arabia, the United Arab Emirates, and Japan; these countries exported more than 1 Mt of elemental sulfur each and accounted for 70.3% of total sulfur trade. Major sulfur importers, in descending order, were China, Morocco, the United States, Tunisia, Brazil, and India, all with imports of more than 1 Mt.

World production of sulfur was slightly higher in 2003 than it was in 2002; consumption was believed to be slightly higher also. Production exceeded consumption in 2003 for the 12th consecutive year, although surpluses were smaller than they had been in recent years (Kitto, 2004).

Prices in most of the world were believed to have averaged higher throughout the year than in 2002, for the second consecutive year. Production of Frasch sulfur was slightly lower than that of 2002; production at the last mine in Poland remained steady. Recovered sulfur production was virtually the same, and byproduct sulfuric acid production increased by 3.5% compared with those of 2002. Supplies of sulfur in all forms continued to exceed demand; worldwide sulfur inventories increased, much of which was stockpiled in Canada, although Canadian stocks actually declined owing to the strong international demand for sulfur. Globally, production of sulfur from pyrites was about the same.

Statistics compiled by the Oil & Gas Journal showed that the United States possessed 20% of the world's total refining capacity and 42% of the world's sulfur recovery capacity derived from oil refineries. The publication listed 717 oil refineries in 118 countries; only about one-half of these countries were reported to have sulfur recovery capacity (Stell, 2003§[1]). Although the sulfur recovery data appeared to be incomplete, analysis of the data showed that most of the countries that reported no sulfur recovery at refineries were small and had developing economies and limited refining industries. In general, as refining economies improve and the refining industries mature, additional efforts are made to reduce atmospheric emissions through installation of sulfur recovery units.

Sulfur levels in motor fuels were being cut worldwide. In 2002, the European Council (EC) speeded up the deadline for mandatory sulfur-free fuels to 2009 from 2011. At that time, 10 ppm will be the maximum quantity of sulfur allowable in gasoline and diesel for all vehicles and equipment including off-road vehicles (Sulphur, 2002a). In 2003, environmental ministers of the EC encouraged member countries to use tax incentives to further speed the introduction of 10-ppm sulfur fuels. The Ministers would like to advance the deadline for compliance to 2005 (Sulphur, 2003j).

Russia's regulations limiting sulfur in fuels are not as strict as those in the European Union (EU). New legislation places the maximum sulfur content for diesel at 350 ppm and for gasoline at 150 ppm by 2004. Efforts were being made to make lower sulfur fuels available for vehicles that will be traveling in the EU to conform to regulations there (Sulphur, 2002b). Japan was working to limit the sulfur content of diesel and gasoline to 10 ppm from 50 ppm and 500 ppm, respectively, by 2008 (Sulphur, 2002a).

The European Commission proposed new regulations limiting the sulfur content of ocean-going ship fuels to 1.5% sulfur for ships operating within three sulfur control areas. As proposed, these limits would reduce sulfur emissions from shipping by 10%. Shipping companies want alternative methods for reducing sulfur emissions, such as cleaning stack gases and allowance trading. Environmental groups argued that the reduction goals were too low, pushing for cuts of 80% through sulfur fuel limits of 0.5% for ships operating within 200 miles of the European Union's coast and 0.2% within 12 miles of the coast (Sulphur, 2003h). Later in the year, the European Parliament proposed new sulfur limits of 0.5% in diesel fuels used in shipping and passenger vessels operating in European waters by 2008. Ships operating in European territory would be limited to 1.5% sulfur fuels by 2011 even if they do not enter European ports. A level of 0.5% would apply to these vessels after 2012. Marine diesel averaged about 3% sulfur in 2003 (Sulphur, 2003e).

World Review

Canada.—Canada was second only to the United States in production of byproduct sulfur and sulfur in all forms. It led the world in exports of elemental sulfur and stockpiled material. The majority of sulfur production came from natural gas plants in Alberta. Sulfur inventories were 14.2 Mt at the end of 2003, a slight decrease from those of 2002. Although some producers added to their stockpiles in some locations, others remelted inventories for shipment, resulting in a net decrease (North American Sulphur Review, 2004). Sulfur recovered from natural gas has declined in Canada for the past 3 years, and that trend is expected to continue. Recovery at refineries should increase, but the largest changes will be as a result of additional production from oil sands. Sulfur from oil sands may not be readily available to the market. Much of the production is at remote locations where market access is limited and the material has been poured to block, the term used for stockpiling sulfur (North American Sulphur Review, 2002a).

Alberta has huge deposits of oil sands with estimated reserves of 300 million barrels (Mbbl) of recoverable crude oil that contain 4% to 5% sulfur (Stevens, 1998). The crude oil resource in oil sands in Alberta is larger than the proven reserves of crude oil in Saudi Arabia (Pok, 2002). As traditional petroleum production in Canada declined, oil sands became a more important source of petroleum for the North American market (Cunningham, 2001). The proportion of Canadian production from oil sands was expected to increase to 21% in 2005 and 30% in 2010 from 9% in 2001 (Pok, 2002). Expansions of oil sands operations were planned by several companies, several existing oil refineries were undergoing conversions to enable the processing of bitumen from oil sands, and pipelines were being built to deliver the bitumen to the refineries from the deposits.

[1]A reference that includes a section mark (§) is found in the Internet Reference Cited section.

Canada's ratification of the Kyoto Protocol, which limits carbon dioxide emissions, put the future of many oil sands operations in doubt. Large quantities of carbon dioxide are produced in the process of upgrading bitumen. The cost of reducing carbon dioxide emissions could increase the cost of producing oil sands too much for at least some of the projects to remain economically feasible. The Province of Alberta was concerned that ratifying the Kyoto Protocol could cost the industry many billions of dollars and many jobs (Cunningham, 2002). Rising costs and the Kyoto Protocol prompted some Canadian oil sands developers to reconsider additional investments. Petro-Canada considered delaying upgrading its Strathcona refinery near Edmonton, Alberta, to process bitumen from oil sands. Another company delayed oil-sands-related spending. Suncor Energy Inc. bought a U.S. refinery to process its high-sulfur synthetic crude, and Canadian Natural Resources Ltd. was considering a similar action. The United States did not intend to ratify the Kyoto Protocol (Sulphur, 2003g).

Kazakhstan.—The Tengiz oilfield and gasfield is the main source of current sulfur production in Kazakhstan. Located on the northeastern shore of the Caspian Sea in western Kazakhstan, Tengiz has been operated by Tengizchevroil (TCO) since 1993. The owners of TCO are ChevronTexaco (50%), ExxonMobil (25%), Kazakhoil National Oil and Gas Co. (Kazakhstan's national oil and gas company) (20%), and LUKARCO (a joint venture between BP and Russian oil company LUKoil Oil Co.) (5%) (Chevron Corp., 2000). One of the world's largest oilfields, Tengiz contains high-quality oil with 0.49% sulfur and associated natural gas that contains 12.5% hydrogen sulfide (Connell and others, 2000).

Late in 2002, disagreements between the Government of Kazakhstan and TCO threatened further development of the Tengiz condensate-and-sour-gas field. Renegotiation of the original terms of the financial agreement between the Government and ChevronTexaco created doubts as to whether TCO would proceed with the second stage of development. In addition to the financial questions, local courts fined the company $73 million for environmental damage caused by the 6 Mt of elemental sulfur stockpiled at the site (Sulphur, 2003k). In 2003, the fine for exceeding the allowable sulfur stockpiling and causing ecological damage at Tengiz was reduced to $7 million from $73 million by the Supreme Court of Kazakhstan. The disagreement over financing of the expansion project prompted the consortium to suspend the expansion until agreement was reached. Following resolution of the conflicts with the Government of Kazakhstan, the expansion proceeded at Tengiz. The Tengiz expansion plan to nearly double oil production includes the reinjection of sour gas, limiting total recovery of sulfur at the site (Sulphur, 2003d).

After some shipments of flaked sulfur were exported by rail to China in 2002, the first shipments of granulated sulfur following the installation of sulfur forming apparatus at Tengiz went to Israel, Spain, and Tunisia in 2003. Stockpiles of 6 Mt of blocked sulfur remain in place, and alternative disposal scenarios were being considered (Sulphur, 2003c). TCO proposed burying excess production in an old uranium mine. The Government rejected this proposal but countered with the possibility of using an old chromium mine (Sulphur, 2003j).

Sulfur also is recovered from the Karachaganak gas-condensate field in Kazakhstan near the Russian border. Because it is close to the Russian gas processing operation in Orenberg, sour gas from Karachaganak is treated at Orenberg. No gas treatment facilities have been installed at the site (Sulfur, 2001a).

Mexico.—Mexico was the second leading supplier of imported recovered sulfur to the United States. The majority of its sulfur is produced at petroleum refineries, and byproduct sulfuric acid is recovered at its smelters. Petróleos Mexicanos S.A. de C.V. was pursuing a program to cut emissions from its refineries to improve the air quality in Mexico by increasing the efficiency of its sulfur recovery units to more than 99%. Nine sulfur recovery units have been completed with a total capacity of 3,440 metric tons per day (t/d) [1.26 million metric tons per year (Mt/yr)]. The improvement process was initiated in 1996 when the North American Free Trade Agreement was ratified and new Mexican environmental laws were enacted. After evaluating existing sulfur recovery units, plans were made to replace or upgrade facilities that did not meet new guidelines. Air quality improvements were to continue (Sulphur, 2003i).

Philippines.—Crew Development Corp. went forward with its attempt to develop the Pamplona native sulfur deposit as a raw material source for a local fertilizer producer. Crew originally considered developing the sulfur deposit to supply its Mindinoro laterite nickel project but encountered difficulties getting permits for the pressure acid leach project. The company was considering commercial development of Pamplona prompted by increased sulfur prices. Pamplona contained 40 Mt of sulfur ore averaging 30% sulfur, as native sulfur and sulfides, that was amenable to open pit mining and another 80 Mt of inferred resources. Crew would produce between 2 and 4 Mt/yr (Sulphur, 2003a).

Russia.—Russia is the second leading sulfur exporter in the world with more than 4 Mt of elemental sulfur exports in 2003 (International Fertilizer Industry Association, 2004). Gazprom's gas processing plants in Astrakhan and Orenburg are the leading producers, totaling more than 5 Mt in 2002 (Sulphur, 2003i).

MMC Norilsk Nickel started a cleanup project at its Siberian nickel smelter that will eventually result in the production of 1 Mt/yr of sulfur. The company also was working on another cleanup project on the Kola Peninsula in cooperation with the Government of Norway. Sulfur emissions by Norilsk's Polar Division were to decrease by 70% by 2010. Sulfur emissions on the Kola Peninsula were to decrease by 90% by 2006 (Sulphur, 2003f).

Outlook

The sulfur industry continued on a path of increased production, slow growth in consumption, higher stocks, and expanded world trade. U.S. production from petroleum refineries is expected to increase substantially in the next few years as expansions, upgrades, and new facilities at existing refineries are completed, thus enabling refiners to increase throughput of crude oil and to process higher sulfur crudes. Production from natural gas operations was higher than it was in 2002, but that trend is not expected to continue. In fact, significant decreases are expected from gas operations in Wyoming, the State in which about 70% of all U.S. natural gas sulfur is recovered. Of four large gas operations in the State, three were expected to experience significant decreases in production beginning in 2003. Production at two operations was decreasing as a natural function of long-term extraction of natural gas. The operator of another gas plant was installing sour gas reinjection apparatus that would eliminate production at that site. The final company recently expanded its operation but was exploring the possibility of storing excess production underground. Theoretically, this material would be available to meet future needs. In reality, however, it represented an option for disposing of unwanted surplus material.

Wyoming sulfur production is predicted to be 27% lower in 2005 than it was in 2002 even without disposal at the fourth operation (North American Sulphur Review, 2002c). If that company chooses to dispose of sulfur rather than market it, material recovered from natural gas processing could become a very small part of the domestic industry.

Worldwide recovered sulfur output is expected to continue to increase. The largest increases in recovered sulfur production through 2005 are expected to come from the Middle East's and Russia's growth in sulfur recovery from natural gas, Canada's expanded oil sands operations, and Asia's improved sulfur recovery at oil refineries. Refineries in developing countries should begin to improve environmental protection measures and eventually approach the environmental standards of plants in Japan, North America, and Western Europe.

Experts from the natural gas industry estimated that the world demand for natural gas will grow by 2.5% per year during the next 20 years for a total 50% increase in demand. Producing 50% more gas means recovering at least an additional 50% in sulfur from that source. Future gas production, however, is likely to come from deeper, hotter, and more sour deposits that will result in even more excess sulfur production unless more efforts are made to develop new large-scale uses for sulfur. Other alternative technologies for reinjection and long-term storage to eliminate some of the excess sulfur supply will require further investigation to handle the quantity of surplus material anticipated (Hyne, 2000).

Byproduct sulfuric acid production will remain depressed in the United States so long as the copper smelters remain idle. With the copper industry's switch to lower cost production processes and producing regions, the four idle smelters may never reopen. BHP Billiton decided to permanently close its Magma, AZ, copper smelter that has been on a care-and-maintenance status since 1999 (North American Sulphur Review, 2003a). Other companies may make similar decisions.

Worldwide, the outlook is different. Because copper production costs in many countries are lower than in the United States, acid production from those countries has not decreased as drastically, and increased production is likely. Environmental controls have been less of a concern in developing countries in the past. Many copper producers in developing and even in developed countries, however, are installing more efficient sulfuric acid plants to limit sulfur dioxide emissions at new and existing smelters. Planned and in-progress improvement projects could increase byproduct acid production significantly, although growth has been slower than previously expected.

Frasch sulfur and pyrites production, however, have little chance of significant long-term increases, although higher sulfur prices have resulted in the temporary increases in pyrites consumption. Because of the continued growth of elemental sulfur recovery for environmental reasons rather than demand, discretionary sulfur has become increasingly less important as demonstrated by the decline of the Frasch sulfur industry. The Frasch process has become the high-cost process for sulfur production. Pyrites, with significant direct production costs, is an even higher cost raw material for sulfuric acid production when the environmental aspects are considered. Discretionary sulfur output should show a steady decline. The decreases will be more pronounced when large operations are closed outright for economic reasons, as was the case in 2000 and 2001.

Sulfur and sulfuric acid will continue to be important in agricultural and industrial applications, although consumption will be less than production. World sulfur demand for fertilizer is forecast to increase by about 2.3% per year for the next 10 years; industrial demand is predicted to grow by 2.2% per year as a result of increased demand for copper and nickel leaching.

The most important changes in sulfur consumption will be in location. Phosphate fertilizer production, where most sulfur is consumed, is projected to increase by about 2.0% per year through 2011. With new and expanding phosphate fertilizer capacity in Australia, China, and India, sulfur demand will grow in these areas at the expense of some phosphate operations elsewhere, thus transferring sulfur demand rather than creating new demand. The effects were already being felt by the U.S. phosphate industry as reflected in the permanent closure of some facilities and reduced production at others. U.S. phosphate products supply domestic requirements, but a large portion of U.S. production is exported. China and India are primary markets for U.S. phosphatic fertilizers. As the phosphate fertilizer industries develop in these countries, some of the markets for U.S. material could be lost. Sulfur will be required for phosphate production at new operations, and more producers will be competing for those markets.

Use of sulfur directly or in compounds as fertilizer should increase, but this use will be dependent on agricultural economies and increased acceptance of the need for sulfur in plant nutrition. If widespread use of plant nutrient sulfur is adopted, then sulfur consumption in that application could be significant; thus far, however, growth has been slow.

Industrial sulfur consumption has more prospects for growth than in recent years, but still not enough to consume all projected surplus production. Conversion to or increases in copper leaching by producers that require significantly more sulfuric acid for the leaching operations than was used in 2003 bode well for the sulfur industry. Nickel pressure acid leach operations were demanding increased quantities of sulfur. Changes in the preferred methods for producing oxygenated gasoline, especially in Canada and the United States, might result in additional alkylation capacity that would require additional sulfuric acid. Other industrial uses show less potential for expansion. Production is expected to surpass demand well into the future.

Unless less traditional uses for elemental sulfur increase significantly, the oversupply situation will result in tremendous stockpiles accumulating around the world. In the 1970s and 1980s, research was conducted that showed the effectiveness of sulfur in several construction uses that held the promise of consuming huge quantities of sulfur in sulfur-extended asphalt and sulfur concretes. In many instances, these materials were found to be superior to the more conventional products, but their use thus far has been very limited. Interest in these materials seemed to be increasing but only in additional research. When sulfur prices are as high as they were in 2003, they are less attractive for unconventional applications where low-cost raw materials are the goal.

Regardless of the prevailing price increases in 2003 that signaled tight supplies, the worldwide oversupply situation is likely to worsen. Unless measures are taken to use more sulfur, either voluntarily or through government mandate, large quantities of excess sulfur could be amassed in many more areas of the world, including the United States.

References Cited

Chevron Corp., 2000, Chevron finalizes additional stake in Tengiz joint venture: San Francisco, CA, Chevron Corp. press release, August 29, 1 p.

Connell, Dave, Ormiston, Bob, Amott, Nick, and Cullum, Irene, 2000, Gas-plant update moves Tengiz field toward 2004 producing target: Oil & Gas Journal, v. 98.24, June 12, p. 64-72.

Cunningham, Chris, 2002, Kyoto debate makes Canada sour: Sulphur, no. 283, November-December, p. 23-24.

Fertilizer Markets, 2000, Main Pass closed: Fertilizer Markets, v. 11, no. 4, September 4, p. 9.

Fialka, J.J., 2003, Off-road vehicles fueled by diesel targeted by EPA: The Wall Street Journal, April 16, p. A4.

Hyne, J.B., 2000, An invisible hill to climb: Sulphur, no. 269, July-August, p. 3.

International Fertilizer Industry Association, 2004, Preliminary sulphur statistics—2003: Paris, France, International Fertilizer Industry Association A/04/79, 6 p.

Kitto, Mike, 2004, Recent trends in the sulphur and sulphuric acid markets: Sulphur, no. 293, July-August, p. 24-28.

McMoRan Exploration Co., 2002, McMoRan Exploration Co. completes sale of sulphur transportation & terminaling assets: New Orleans, LA, McMoRan Exploration Co. news release, June 14, 1 p.

Nakamura, David, 2002, World refining capacity climbs to highest level ever: Oil & Gas Journal, v. 100.52, December 23, p. 62-66.

Nakamura, David, 2003, Refining capacity creeps higher in 2003: Oil & Gas Journal, v. 101.52, December 22, p. 64-69.

North American Sulphur Review, 2002a, Canadian production stabilizes, but an increasing proportion of it comes from oil sands: North American Sulphur Review, v. 13, no. 10, October, p. 1-2.

North American Sulphur Review, 2002b, News & developments: North American Sulphur Review, v. 13, no. 10, October, p. 2.

North American Sulphur Review, 2003a, In brief: North American Sulphur Review, v. 14, no. 11, November, p. 2-3.

North American Sulphur Review, 2003b, News & developments: North American Sulphur Review, v. 14, no. 11, November, p. 1.

North American Sulphur Review, 2004, North American sulphur balance is reviewed: North American Sulphur Review, v. 15, no. 7, July, p. 1.

Oil & Gas Journal, 2000, EPA issues rule limiting US gasoline sulfur: Oil & Gas Journal, v. 98, no. 1, January 3, p. 26-27.

Oil & Gas Journal, 2001, Government developments: Oil & Gas Journal, v. 99.1, January 1, p. 7.

Oil & Gas Journal, 2003a, Industry trends: Oil & Gas Journal, v. 101.29, July 28, p. 7.

Oil & Gas Journal, 2003b, US refiners on target to meet low-sulfur highway diesel rules: Oil & Gas Journal, v. 101.43, November 10, p. 34.

Pok, Joe, 2002, Oil sands developments in Alberta and the implications on sulfur supply: International Fertilizer Industry Association Production and International Trade Conference, Quebec City, Quebec, Canada, October 16-18, 2002, Presentation, 15 p.

Shelton, J.E., 1978, Sulfur and pyrites: U.S. Bureau of Mines Minerals Yearbook 1976, v. I, p. 1287-1307.

Stevens, Jason, 1998, Oil sands projects gather pace: Sulphur, no. 254, January-February, p. 27-30.

Sulphur, 2001a, Rising profile: Sulphur, no. 273, March-April, p. 17-19.

Sulphur, 2001b, Three refiners ask for time out: Sulphur, no. 274, May-June, p. 30-31.

Sulphur, 2002a, Government moves into line with EU on sulphur in auto fuels: Sulphur, no. 279, March-April, p. 10.

Sulphur, 2002b, Russia can meet EU fuel spec—In part: Sulphur, no. 281, July-August, p. 9-10.

Sulphur, 2003a, Crew wins go-ahead for native sulphur sampling: Sulphur, no. 288, September-October, p.10.

Sulphur, 2003b, Kazahk granules: Sulphur, no. 285, March-April, p. 6.

Sulphur, 2003c, Life less expensive for Tengiz S producers: Sulphur, no. 286, May-June, p. 11.

Sulphur, 2003d, MEPs make waves over marine fuel S level: Sulphur, no. 287, July-August, p. 10.

Sulphur, 2003e, Salaries and Kyoto make Petro-Canada rethink oil sands strategy: Sulphur, no. 287, July-August, p. 8.

Sulphur, 2003f, Ship owners call for sulphur trading and stack clean-up: Sulphur, no. 285, March-April, p. 8-9.

Sulphur, 2003g, Sulphur markets summit in Vienna: Sulphur, no. 284, January-February, p. 17-29.

Sulphur, 2003h, TCO seeks out dump site for sulphur: Sulphur, no. 285, March-April, p. 10.

Sulphur, 2003i, TCO settles differences with Kazakh government: Sulphur, no. 284, January-February, p. 10-12.

Sulphur, 2003j, Transport ministers want sulphur-free fuels by 2005: Sulphur, no. 287, July-August, p. 10-11.

U.S. Census Bureau, 2004, Inorganic fertilizer materials and related products—First quarter 2004: U.S. Census Bureau MQ325B(04)-1, July, 5 p.

Internet Reference Cited

Stell, Jeannie, 2003, 2002 worldwide refining survey, accessed February 23, 2004, at URL http://downloads.pennet.com/pnet/surveys/ogj/wwrefcap.pdf.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Sulfur. Ch. in Mineral Commodity Summaries, annual.
Sulfur. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Sulfur. Mineral Industry Surveys, monthly.

Other

Chemical and Engineering News, weekly.
Chemical Engineering, weekly.

Chemical Market Reporter, weekly.
Chemical Week, weekly.
European Chemical News, weekly.
Fertilizer International, monthly.
Fertilizer Week America, weekly.
Green Markets, weekly.
Industrial Minerals, monthly.
Oil & Gas Journal, weekly.
PentaSul North America Sulphur Review, monthly.
Sulfur. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Sulphur, bimonthly.

TABLE 1
SALIENT SULFUR STATISTICS[1]

(Thousand metric tons of sulfur content and thousand dollars unless otherwise specified)

	1999	2000	2001	2002	2003
United States:					
Production:					
Frasch	1,780 e	900 e	--	--	--
Recovered[2]	8,360	8,590	8,490	8,500	8,920
Other	1,320	1,030	982	772	683
Total[e]	11,500	10,500	9,470	9,270	9,600
Shipments:					
Frasch	W	W	--	--	--
Recovered[2]	9,940 [3]	9,710 [3]	8,470	8,490	8,920
Other	1,320	1,030	982	772	683
Total	11,300	10,700	9,450	9,260	9,600
Exports:					
Elemental[4]	685	762	675	687	742
Sulfuric acid	51	62	69	48	67
Imports:					
Elemental	2,580	2,330	1,730	2,560	2,870
Sulfuric acid	447	463	462	346	297
Consumption, all forms[5]	13,600 r	12,700	10,900	11,400	12,000
Stocks, December 31, producer, Frasch and recovered	451	208	232	181	206
Value:					
Shipments, free on board (f.o.b.) mine or plant:					
Frasch	W	W	--	--	--
Recovered[2]	$376,000 [3]	$240,000 [3]	$84,700 e	$100,000 e	$256,000 e
Other	$66,400	$55,100	$49,500	$35,500	$34,000
Total	$442,000	$295,000	$134,000	$136,000 r	$290,000
Exports, elemental[6]	$35,800	$53,700	$48,800	$40,000	$46,100
Imports, elemental	$51,600	$39,400	$22,100	$26,800	$70,600
Price, elemental, f.o.b. mine or plant dollars per metric ton	37.81	24.73	10.01 e	11.84 e	28.71 e
World, production, all forms (including pyrites)	58,500 r	59,700 r	60,400 r	60,500 r	61,800 e

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included with "United States, value, recovered." -- Zero.
[1]Data are rounded to no more than three significant digits except prices; may not add to totals shown.
[2]Includes U.S. Virgin Islands.
[3]Includes corresponding Frasch sulfur data.
[4]Includes exports from the U.S. Virgin Islands to foreign countries.
[5]Consumption is calculated as shipments minus exports plus imports.
[6]Includes value of exports from the U.S. Virgin Islands to foreign countries.

TABLE 2

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE[1]

(Thousand metric tons and thousand dollars)

State	2002			2003		
		Shipments			Shipments	
	Production	Quantity	Value[e]	Production	Quantity	Value[e]
Alabama	269	271	3,880	234	231	7,710
California	965	962	3,590	1,070	1,060	20,600
Illinois	414	412	1,420	466	460	11,700
Louisiana	1,160	1,160	15,700	1,210	1,210	65,400
Michigan and Minnesota	35	34	119	39	39	195
Mississippi	545	547	24,900	534	548	19,700
New Mexico	43	43	(2)	42	42	(2)
Ohio	115	116	1,260	104	105	4,070
Texas	2,750	2,730	41,600	2,900	2,910	81,600
Washington	105	106	(2)	122	122	(2)
Wyoming	1,340	1,360	2,640	1,360	1,360	16,900
Other[3]	762 r	755 r	5,430	834	837	28,100
Total	8,500	8,490	100,000	8,920	8,920	256,000

[e]Estimated. [r]Revised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Some sulfur producers in this State incur expenses to make their production available to consumers.

[3]Includes Arkansas, Colorado, Delaware, Florida, Indiana, Kansas, Kentucky, Montana, New Jersey, North Dakota, Pennsylvania, Utah, Virginia, Wisconsin, and the U.S. Virgin Islands.

TABLE 3
RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT[1]

(Thousand metric tons)

	2002		2003	
District and source	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	233	233	229	232
Natural gas	27	27	26	26
Total	260	260	255	257
PAD 2:				
Petroleum and coke	852	850	904	896
Natural gas	48	47	44	44
Total	900	897	948	940
PAD 3:[2]				
Petroleum and coke	4,440	4,420	4,430	4,470
Natural gas	428	429	617	613
Total	4,870	4,850	5,050	5,080
PAD 4 and 5:				
Petroleum and coke	1,220	1,220	1,410	1,380
Natural gas	1,250	1,260	1,260	1,260
Total	2,470	2,480	2,670	2,640
Grand total:	8,500	8,490	8,920	8,920
Of which:				
Petroleum and coke	6,750	6,720	6,970	6,970
Natural gas	1,760	1,770	1,950	1,940

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes the U.S. Virgin Islands.

TABLE 4

BYPRODUCT SULFURIC ACID PRODUCED IN THE UNITED STATES[1, 2]

(Thousand metric tons of sulfur content and thousand dollars)

Type of plant	2002	2003
Copper[3]	695	590
Zinc[4]	50	51
Lead and molybdenum[4]	28	42
Total:		
Quantity	772	683
Value	35,500	34,000

[1]May include acid produced from imported raw materials.

[2]Data are rounded to no more than three significant digits, may not add to totals shown.

[3]Excludes acid made from pyrites concentrates.

[4]Excludes acid made from native sulfur.

TABLE 5

CONSUMPTION OF SULFUR IN THE UNITED STATES[1, 2, 3]

(Thousand metric tons)

	2002	2003
Elemental sulfur:		
Shipments[4]	8,490	8,920
Exports	687	742
Imports	2,560	2,870
Total	10,400	11,000
Byproduct sulfuric acid:		
Shipments[4]	772	683
Exports[5]	48	67
Imports[5]	346	297
Grand total	11,400	12,000

[1]Crude sulfur or sulfur content.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Consumption is calculated as shipments minus exports plus imports.

[4]Includes the U.S. Virgin Islands.

[5]May include sulfuric acid other than byproduct.

TABLE 6
SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE[1]

(Thousand metric tons of sulfur content)

		Elemental sulfur[2]		Sulfuric acid (sulfur equivalent)		Total	
SIC[3]	End use	2002	2003	2002	2003	2002	2003
102	Copper ores	--	--	707 r	421	707	421
1094	Uranium and vanadium ores	--	--	2	4	2	4
10	Other ores	--	--	1	58	1	58
26, 261	Pulpmills and paper products	W	W	122	225	122	225
28, 285, 286, 2816	Inorganic pigments paints and allied products, industrial organic chemicals, other chemical products[4]	--	5	27	71	27	76
281	Other inorganic chemicals	W	188	50	97	50	285
282, 2822	Synthetic rubber and other plastic materials and synthetics	--	--	66	82	66	82
2823	Cellulosic fibers including rayon	--	--	6	1	6	1
283	Drugs	--	--	2	2	2	2
284	Soaps and detergents	W	--	--	2	--	2
286	Industrial organic chemicals	--	--	4	22	4	22
2873	Nitrogenous fertilizers	--	--	105	206	105	206
2874	Phosphatic fertilizers	--	--	6,660 r	6,660	6,660 r	6,660
2879	Pesticides	--	--	8	11	8	11
287	Other agricultural chemicals	1,650	1,590	29	46	1,680	1,630
2892	Explosives	--	--	8	10	8	10
2899	Water-treating compounds	--	--	59	98	59	98
28	Other chemical products	--	--	21	45	21	45
29, 291	Petroleum refining and other petroleum and coal products	2,390	3,700	90	140	2,480	3,840
331	Steel pickling	--	--	7	58	7	58
333	Nonferrous metals	--	--	2	3	2	3
33	Other primary metals	--	--	7	9	7	9
3691	Storage batteries (acid)	--	--	3	13	3	13
	Exported sulfuric acid	--	--	334	1,420	334	1,420
	Total identified	4,040	5,480	8,320 r	9,700	12,400 r	15,200
	Unidentified	248	678	52	409	300	1,090
	Grand total	4,290	6,160	8,380 r	10,100	12,700 r	16,300

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Unidentified." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Does not include elemental sulfur used for production of sulfuric acid.
[3]Standard industrial classification.
[4]No elemental sulfur was used in inorganic pigments and paints and allied products.

TABLE 7

U.S. EXPORTS OF ELEMENTAL SULFUR, BY COUNTRY[1, 2]

(Thousand metric tons and thousand dollars)

Country	2002 Quantity	2002 Value	2003 Quantity	2003 Value
Brazil	136	4,270	116	6,500
Canada	50	5,290	45	5,440
China	280	13,700	265	16,600
Mexico	41	2,800	31	2,220
Morocco	156	6,490	236	9,230
Other	24 r	7,500 r	49	6,070
Total	687	40,000	742	46,100

[r]Revised.

[1]Includes exports from the U.S. Virgin Islands.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 8

U.S. EXPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY[1]

	2002		2003	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	129,000	$6,670	164,000	$11,200
China	525	586	529	313
Dominican Republic	2,540	146	2,550	217
Israel	216	297	1,120	336
Japan	507	154	135	312
Korea, Republic of	472	154	337	78
Mexico	3,080	505	4,030	471
Netherlands Antilles	20	5	11,200	689
Saudi Arabia	1,020	1,170	861	1,340
Singapore	111	117	185	56
Taiwan	1,470	621	547	461
Trinidad and Tobago	1,990	277	6,450	326
United Kingdom	257	83	282	231
Venezuela	--	--	2,700	211
Other	6,530 r	1,980 r	9,950	2,580
Total	147,000	12,800	205,000	18,800

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS OF ELEMENTAL SULFUR, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

Country	2002 Quantity	2002 Value[2]	2003 Quantity	2003 Value[2]
Canada	1,950 e	9,450	2,080 e	32,000
Mexico	430	11,300	534	26,500
Other	180	6,050	253	12,000
Total	2,560 e	26,800	2,870 e	70,600

[e]Estimated.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Declared customs valuation.

Source: U.S. Census Bureau as adjusted by the U.S. Geological Survey.

TABLE 10

U.S. IMPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY[1]

	2002		2003	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Canada	615,000	$20,700	386,000	$17,800
Germany	99,200	2,970	76,800	2,570
Mexico	97,400	7,900	167,000	2,450
Spain	10,300	493	62,400	3,140
Other	237,000 r	14,400 r	216,000	13,300
Total	1,060,000	46,400	908,000	39,200

[r]Revised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Declared cost, insurance, and freight paid by shipper valuation.

Source: U.S. Census Bureau.

TABLE 11

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1, 2]

(Thousand metric tons)

Country and source[3]	1999	2000	2001	2002	2003[e]
Australia, byproduct:[e]					
Metallurgy	441	654	817	899	863
Petroleum	25	30	45	60	60
Total	466	684	862	959	923
Canada, byproduct:					
Metallurgy	1,159 r	1,167	1,124 r	1,109 r	969 [4]
Natural gas, petroleum, tar sands	8,656 r	8,621 r	8,620 r	7,816 r	8,061 [4]
Total	9,815 r	9,788 r	9,744 r	8,925 r	9,030 [4]
Chile, byproduct, metallurgy[e]	1,040	1,100	1,160	1,275 [4]	1,300
China:[e]					
Elemental	280	290	290	290	290
Pyrites	3,860	3,370	3,090	3,240	3,400
Byproduct, metallurgy	1,630	1,900	2,000	2,200	2,400
Total	5,770	5,560	5,380	5,730	6,090
Finland:[e]					
Pyrites	380	260 r	270 r	359 r	341
Byproduct:					
Metallurgy	299	283 r	227 r	308 r	305
Petroleum	42	46 r	46 r	55 r	60
Total	721	589 r	543 r	722 r	706
France, byproduct:[e]					
Natural gas	600	600	600	500	500
Petroleum	250	250	250	250	250
Unspecified	250	260	250	250	250
Total	1,100	1,110	1,100	1,000	1,000
Germany, byproduct:					
Pyrites	30	30	61	--	-- [4]
Byproduct:					
Metallurgy	504 r	618 r	684 r	754 r	697 [4]
Natural gas and petroleum	1,824 r	1,753 r	1,749 r	1,745 r	1,661 [4]
Unspecified	-- r	-- r	-- r	-- r	-- [4]
Total	2,358 r	2,401 r	2,494 r	2,499 r	2,358 [4]
India:[e]					
Pyrites	32	32	32	32 r	32
Byproduct:					
Metallurgy	261	359	458	458 r	539
Natural gas and petroleum	101	376	526 r	371 r	451
Total	394	767	1,020 r	861 r	1,020
Iran, byproduct:[e]					
Metallurgy	47	50	50	50	50
Natural gas and petroleum	963	963	880 r	1,200 r	1,310
Total	1,010	1,010	930 r	1,250 r	1,360
Italy, byproduct:[e]					
Metallurgy	193	203	203	142	119
Petroleum	485	490	540	560	565
Total	678 [4]	693 [4]	743	702	684
Japan:					
Pyrites[e]	41	30	30	25	25
Byproduct:					
Metallurgy	1,361	1,384	1,319	1,326 r	1,281 [4]
Petroleum	2,060	2,072	2,424	1,865	2,000
Total	3,462	3,486	3,773	3,216 r	3,310
Kazakhstan, byproduct:[e]					
Metallurgy	245	300	310 r	260 r	325
Natural gas and petroleum	1,070	1,200	1,400	1,600 r	1,600
Total	1,320	1,500	1,710 r	1,860 r	1,930
Korea, Republic of, byproduct:[e]					
Metallurgy	528	572	665	680 r	690
Petroleum	600	600	600	610	610
Total	1,130	1,170	1,270	1,290 r	1,300

See footnotes at end of table.

TABLE 11--Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1, 2]

(Thousand metric tons)

Country and source[3]	1999	2000	2001	2002	2003[e]
Kuwait, byproduct, natural gas and petroleum[e]	639	512	524	634	714
Mexico, byproduct:					
Metallurgy	474	474	572 e	575 e	575
Natural gas and petroleum	860	851	878	877 r	1,034 4
Total	1,334	1,325	1,450	1,452 r	1,610
Netherlands, byproduct:[e]					
Metallurgy	129	123	126	124	119
Petroleum	445	428 4	384	373	408
Total	574	551	510	497	527
Poland:[5]					
Frasch	1,172	1,482	942	760	750
Byproduct:					
Metallurgy	278	279	277	275 e	275
Petroleum	74 e	70 e	133	180	150
Total	1,524	1,831	1,352	1,220 e	1,180
Russia:[e, 6]					
Native	50	50	50	50	50
Pyrites	300	350	400	400	450
Byproduct, natural gas	4,405 4	4,900	5,300	5,400	5,600
Other	510	600	500	500	500
Total	5,265 4	5,900	6,250	6,350	6,600
Saudi Arabia, byproduct, all sources	1,940	2,101	2,350 e	2,360 r, e	2,400
Spain:					
Pyrites	388	138	71 e	--	--
Byproduct:[e]					
Coal, lignite, gasification	2	1	1	1	1
Metallurgy	455	454	461	544	560
Petroleum	110	115	135	140	145
Total	955	708	668	685	706
United Arab Emirates, byproduct, natural gas and petroleum[e]	1,089 4	1,120	1,490	1,900	1,900
United States:					
Frasch	1,780 e	900 e	--	--	-- 4
Byproduct:					
Metallurgy	1,320	1,030	982	772	683 4
Natural gas	2,150	2,230	2,000	1,760	1,940 4
Petroleum	6,210	6,360	6,480	6,750	6,970 4
Total	11,500	10,500	9,470	9,270	9,600 4
Other:[e, 7]					
Frasch	23	24	24	23 r	23
Native	212 r	422 r	457 r	449 r	216
Pyrites	271 r	245 r	356 r	358 r	367
Byproduct:					
Metallurgy	914	949	1,120 r	1,390 r	1,320
Natural gas	160 r	196 r	226 r	226 r	226
Natural gas, petroleum, tar sands, undifferentiated	441 r	766 r	785 r	808 r	833
Petroleum	864 r	962 r	873 r	896 r	879
Unspecified	1,310	1,410	1,440 r	1,380	1,400
Total	4,190 r	4,970 r	5,280 r	5,530 r	5,260
Grand total:	58,500 r	59,700 r	60,400 r	60,500 r	61,800
Of which:					
Frasch	2,980	2,410	966	783 r	773
Native[8]	542 r	762 r	797 r	789 r	556
Pyrites	5,300 r	4,450 r	4,310 r	4,410 r	4,620
Byproduct:					
Coal, lignite, gasification[e]	2	1	1	1	1
Metallurgy	11,400 r	12,000 r	12,700 r	13,200 r	13,200
Natural gas	7,310 r	7,920 r	8,130 r	7,880 r	8,270
Natural gas, petroleum, tar sands, undifferentiated	15,800 r	16,300 r	17,000 r	17,100 r	17,700
Petroleum	11,200 r	11,500 r	12,000 r	11,800 r	12,100
Unspecified	4,010 r	4,370 r	4,540 r	4,490 r	4,550

See footnotes at end of table.

TABLE 11--Continued

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1, 2]

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 22, 2004.

[3]The term "Source" reflects the means of collecting sulfur and the type of raw material. Sources listed include the following: Frasch recovery; native comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch); pyrites (whether or not the sulfur is recovered in the elemental form or as acid); byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers; and recovery from processing mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded, because to include it would result in double counting. Production of Frasch sulfur, other native sulfur, pyrite-derived sulfur, mined gypsum derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of origin of the extracted raw materials. In contrast, byproduct recovery from metallurgical operations, petroleum refinieries, and spent oxides are credited to the nation where the recovery takes place, which is not the original source country of the crude product from which the sulfur is extracted.

[4]Reported figure.

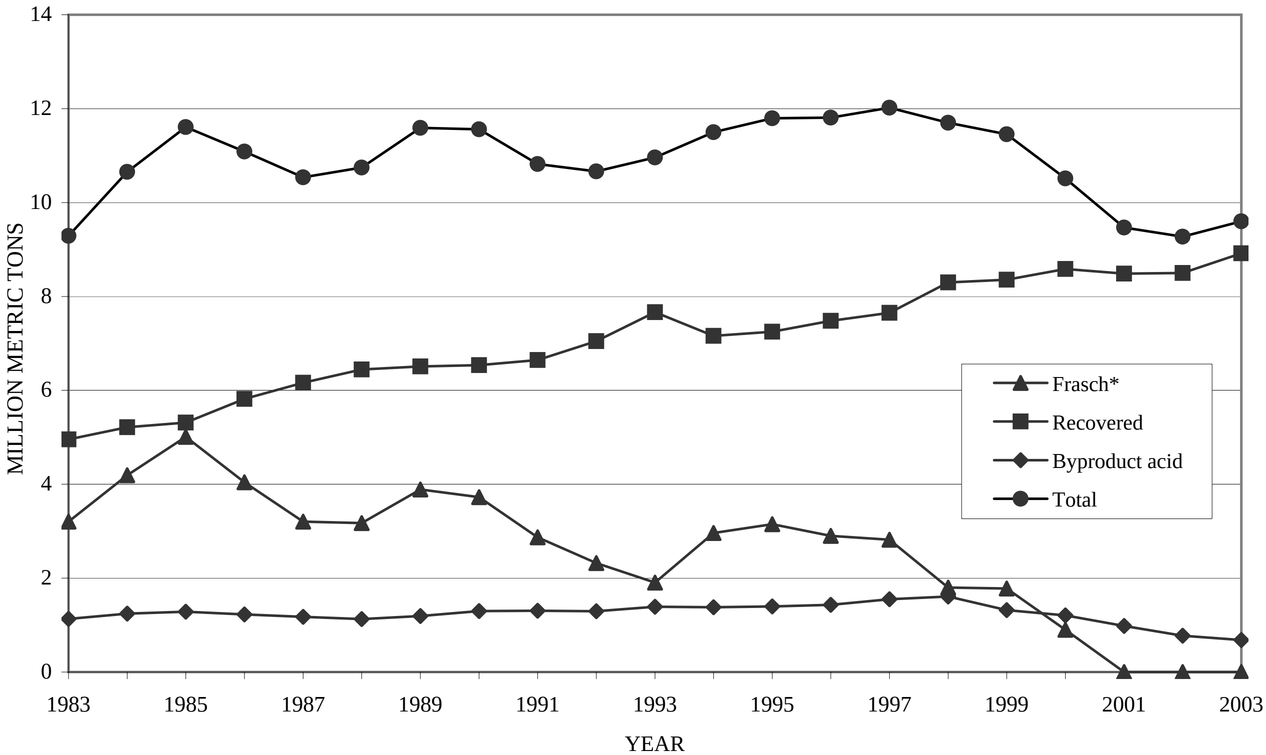
[5]Official Polish sources report total Frasch and native mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources.

[6]Sulfur is believed to be produced from Frasch and as a petroleum byproduct; however, information is inadequate to formulate estimates.

[7]Except for the above mentioned countries, "Other" includes Albania, Algeria, Aruba, Austria, Bahrain, Belarus, Belgium, Bosnia and Herzegovina, Brazil, Bulgaria, Colombia, Croatia, Cuba, the Czech Republic, Denmark, Ecuador, Egypt, Greece, Hungary, Indonesia, Iraq, Israel, North Korea, Kuwait, Libya, Macedonia, Namibia, the Netherlands Antilles, Norway, Oman, Pakistan, Peru, the Philippines, Portugal, Qatar, Romania, Serbia and Montenegro, Singapore, Slovakia, South Africa, Sweden, Switzerland, Syria, Taiwan, Trinidad and Tobago, Turkey, Turkmenistan, Ukraine, the United Kingdom, Uruguay, Uzbekistan, Venezuela, Zambia, and Zimbabwe.

[8]Includes "China, elemental."

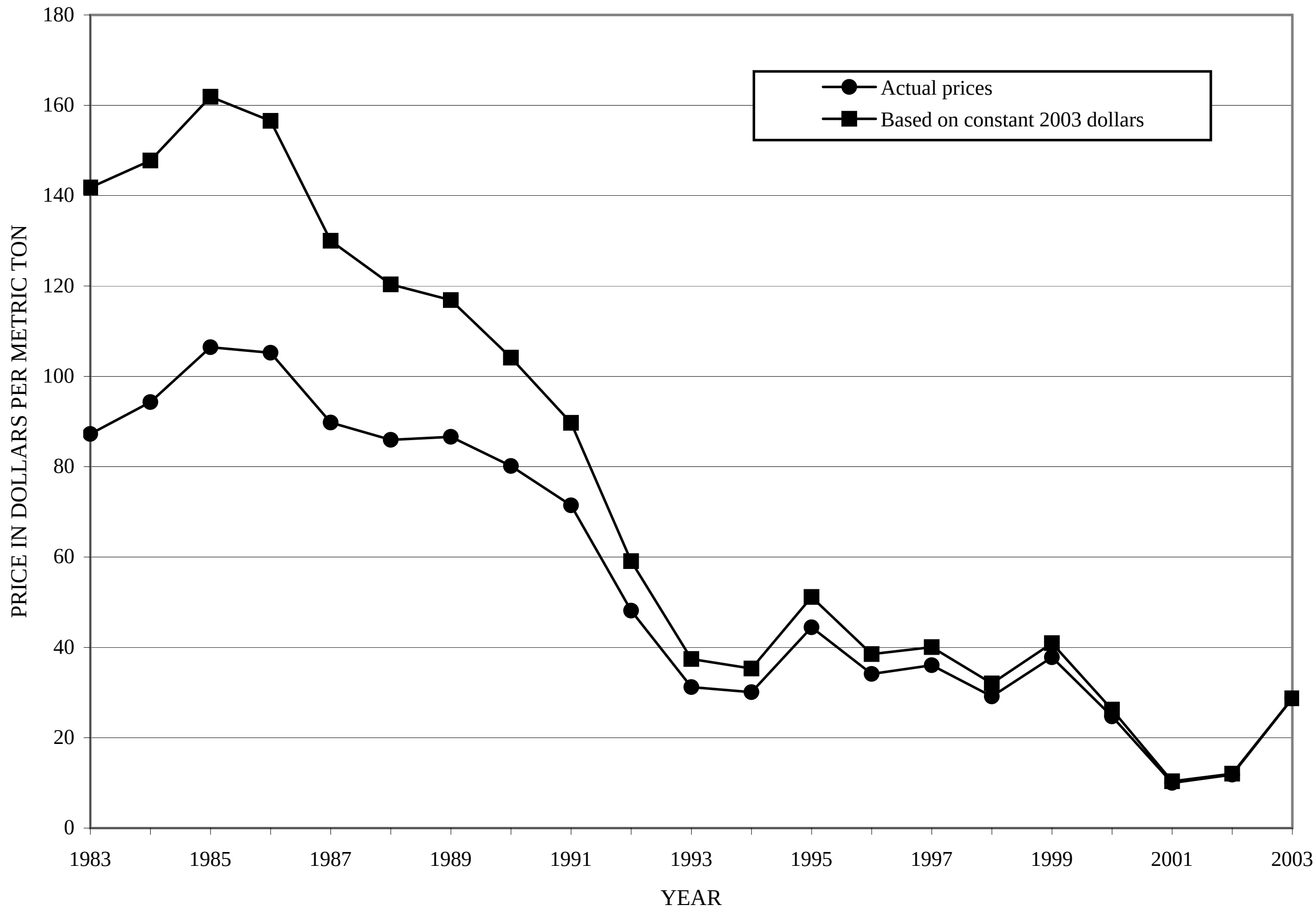
FIGURE 1
TRENDS IN SULFUR PRODUCTION IN THE UNITED STATES



*Includes 10 months of Frasch data for 1993; the other 2 months are included with the recovered sulfur data to conform with proprietary data requirements. Data are estimates for 1994 through 2000.

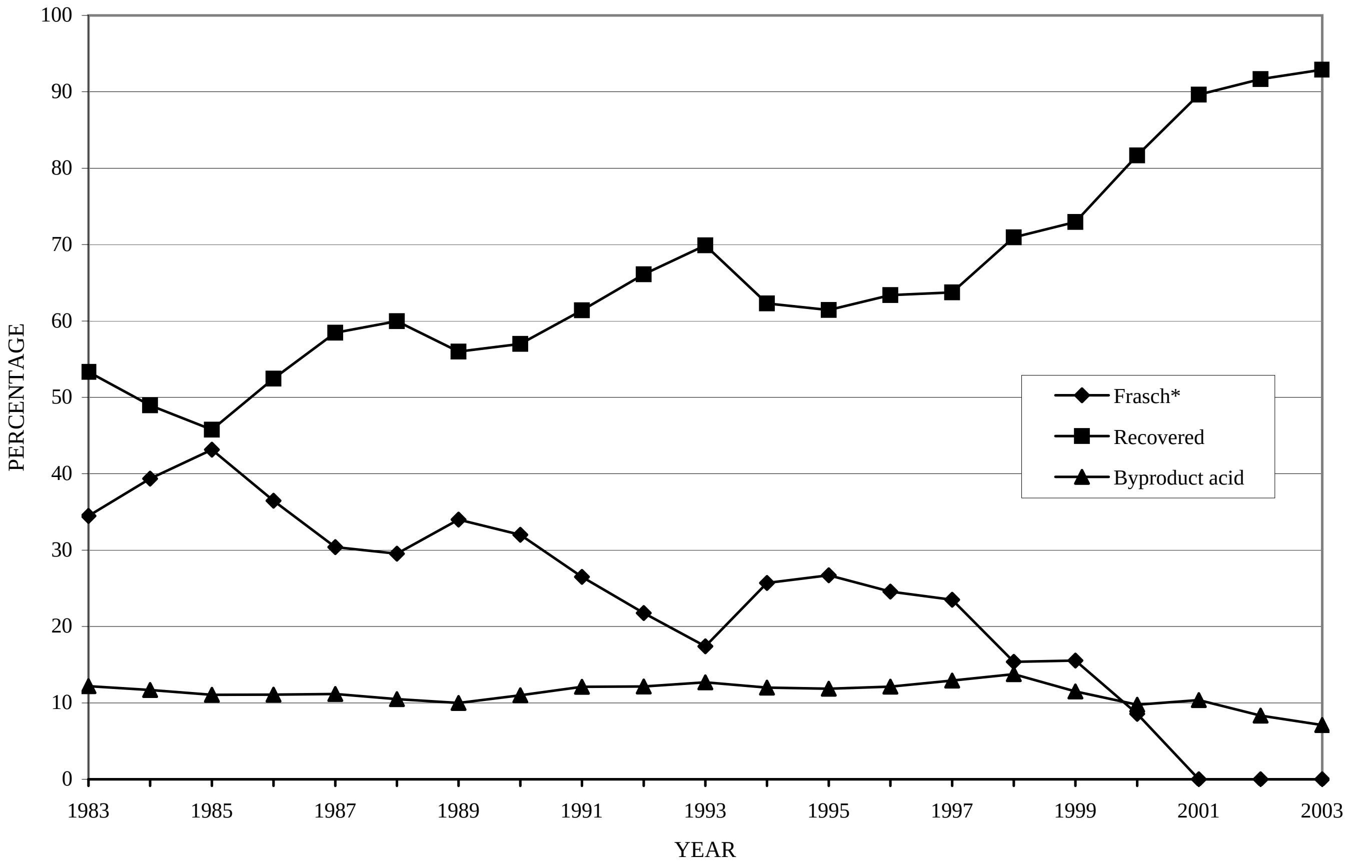
FIGURE 2

ESTIMATED AVERAGE PRICE OF SULFUR IN ACTUAL AND CONSTANT DOLLARS[1]



[1]Based on the reported average value for elemental sulfur (Frasch and recovered), free on board mine and/or plant.

FIGURE 3
PERCENTAGE OF SULFUR PRODUCTION BY SOURCE



*Includes 10 months of Frasch data for 1993; the other 2 months are included with the recovered sulfur data to conform with proprietary data requirements. Data are estimates for 1994 through 2000.

FIGURE 4
TRENDS IN SALIENT SULFUR STATISTICS